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Assessing the Changes in Tehran' Ecosystems Using the Landscape Metrics and Carbon Sequestration Rates

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Abstract:

Today, metropolitan cities face many problems, include excessive population and its problems, such as air pollution, soil, water, traffic, destruction and degradation of natural resources. Tehran, as the largest metropolis in Iran during the last decade, has faced numerous problems in the environmental, physical, economic and social infrastructures, which has reduced the quality of the environment. Therefore, attention to ecosystem services on the one hand and the image of urban land on the other hand can improve the quality of urban environments. The purpose of this study is to map ecosystem services and landmarks of Tehran. It also examines the relationship between measurements and ecosystem services and air quality parameters. To do this, Landsat satellite images were first extracted in 1986, 1996, 2008, and 2016, and land use maps were compiled in six categories of human, green spaces, roads, industries, agriculture, and lands. The accuracy of the maps was investigated using general accuracy and Kappa coefficient. The layout analysis method was used to calculate the measurements using the Faragstats 4.0 software at the surface level and classroom level. The city shifts were compared using measurements. Data on air quality parameters were prepared for a decade (1396-1386), and concentrations of contaminants were mapped to inverse distance. The correlation of the measures with the concentration of pollutants was investigated using Pearson correlation test in two periods of 2008 and 2016. The carbon sequestration map was developed as an ecosystem service using InVEST 3.0.0 software for periods 1986-1996, 1996 to 2008, 2008 to 2016, and period 1986 to 2016. The results of landmark analysis showed that the city of Tehran has undergone many changes over the course of thirty years, which has led to the destruction and fragmentation of the land, and also the city's texture has progressed towards compression and fine graining. During this time, the city has experienced a great deal of expansion. The carbon sequestration results in a reduction and loss of carbon sequestration, especially in the north of the study area over a 30-year period. The results of Pearson's correlation analysis between carbon sequestration and air quality parameters show a significant correlation with ozone, carbon monoxide and sulfur dioxide. The results of Pearson correlation test showed that there is a significant relationship between measures and concentrations of pollutants as well as carbon sequestration. This study showed that the use and application of measures and attention to ecosystem services for urban management is necessary.

Keywords: carbon sequestration, city of Tehran, gradient analysis, landscape metrics

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Expanded Abstract

Introduction

The over half of world populationare living in cities andcounties. It is expected 66% of them will live in and around the cities in 2050 (World Population Prospects, the 2012 Revision). Increasing in population growth and development, especially in cities, has changed the ecology of entire earth planet (Alberti et al., 2008; Rockstrom et al., 2009). Based on the report of millennium ecosystem assessment, ecosystems have wider and fasterchanged by human during recent 50-year compared to any other temporal period in human history (Millennium Ecosystem Assessment, 2005). These extensive changes in ecosystem structure and function lead to disturbance in providing ecosystem services potential (Vitousek et al., 1997). Considering evidences, extended disturbancesin ecosystem structure and function are regarded as a factor for reducing ecosystem services during several recent decades, which cannot been perceived perfectly as yet (Raudsepp-Hearne et al., 2010) and result in arising some problems such as the global phenomenon of climate change, contamination of air, occurrence of erosion, flow offlood, reduction of water quality, extinction of species and loss of natural landscape.

Nowadays, metropolitans are facing to various problems such as over population and its negative outcomes including the air, soil and water pollution, destruction of natural resources and traffic. Considering large changes in city of Tehran, as the largest metropolis of Iran, due to irregular population growth and urbanization growth, this city has faced to the different problems in the field of environmental, physical, economic and social infrastructures during recent decades and these problems lead to reducing the environment quality. The present study sought to assess urban changes by using landscape metrics and their relationship with carbon sequestration rates and storage in city of Tehran. The evaluation of the trend of ecosystem changes by using landscape metrics can represent the reduction of services along with changes.

Material and Method

City of Tehran as the most populous metropolitan and capital of Iran with an area of 720 km^2 is located in the northern half of the country. The altitude of this city is varies between 1100 m to 1700 m. In this study, in the first step, base maps were extracted from Landsat 5 satellite images related to 18.6.1986, 13.6.1996 and 1.7.2008 and Landsat 8 images related to 20.6.2016, then, land-use map was prepared with intended classes (spatial resolution= 30 m). Based on the nature of the present study, uses were classified into six classes involving man-made (residential, commercial, administrative and urban services), green space, agricultural, industrial-workshop, barren and non-built, road and transit routes classes. These maps were usedas base mapsto calculate landscape metrics. Before anything, vector format was converted to raster format since landscape analyses are conducted in raster-based GIS software. The optimum pixel size of the vectorland-use map related to city of Tehran with raster model was set at 30 m. Gradient analysis which was first developed by Whittaker (1975) to analyze vegetation is regarded more efficient and can be performed by using FRAGSTATS 3.3. software. Urban expansion was also studied through this analysis based on landscape metrics (Zhang et al., 2004). Regarding gradient analysis, the area under study was divided into 113 km buffers starting from city center and analyses were conducted in these buffers. Metrics were calculated by using FRAGSTATS 3.3 software on the class level. Four metrics of the percentage of lands cover, number of patch, meanpatch size and area-weighted mean patch fractal dimension were selected among all metrics to compare changes.

InVEST is considered as one of the models of carbon storage and sequestration, in which the information related to the amount of wood harvest, harvested production, destruction, storages existing in the four carbon pools of above and underground biomasses, soil organic matter and dead organic matter, current carbon storage in landscape. Carbon sequestration in any time are estimated based on

land cover or land-use map (Tallis et al., 2011).
The annual mean of the air quality parameters including PM10, CO, NO_2, SO_2 and O_3 was determined in the air pollution monitoring stations located in city of Tehran during two temporal ranges of 2006 and 2016 and interpolated through inverse-distance weighting. Further, the correlation between air quality parameters and amount of carbon sequestration rates during two ranges of 2008 and 2016 were evaluated by using Pearson's correlation coeeficient.

Results
After classifying satellite images, the accuracy of classified images is assessed. Overall accuracy and Kappa coefficient are regarded as more common components for assessment (Foody, 1992), which were used to evaluate classification accuracy in the present study. Kappa coefficient calculates classification accuracy with respect to a completely-random classification in which each image was randomly classified (Mitsova et al., 2011). It is considered as one of criteria for assessing map accuracy, represents agreement between the results of classification and reality of land. Kappa coefficient varies between zero and one, where one indicates 100% agreement between classified layer and reality of land (Congalton & Green, 2009).
The land-use maps of area were prepared in six classes of man-made, barren, agricultural, green space, industrial-workshop and road network during four temporal ranges by using satellite images. The spatial resolution of all images was 30 m, which was regarded appropriate for the study. These maps were used to as base map analyze landscape. Class-level analyses were used in six classes in the class level.

Discussion and Conclusion
Land-use changes during a 30-year range represent the replacement of natural (barren lands) and semi-natural resources (agricultural lands) by man-made areas, which result in increasing residential areas and developing and expanding road network and urban green space. The addition of population rate and urbanization growth are regarded as main factors for changing landscape structure and function and affecting the climate of area (Orville et al., 2000). An increase in artificial or man-made patches indicates the destruction of lands, while an addition of the number and diversity of natural patches results in enhancing ecosystem relationships and land sustainability (Botequilha % Ahern, 2002). Further, increasing the number of man-made patches leads to the reduction of continuity and transmission between natural covers (McGarigal & Marks, 1995).
Based on the metrics analysis, extensive changes occur in landscape. The number of patches in man-made class increases over the time and this addition is significant, especially in zone 4. An addition of the number of patches is regarded as an important index for the decomposition of land and results in enhancing the destruction of land. In fact, it represents decomposition and reduction of continuity (McGarigal & Marks, 1995).
Regarding the metric of mean patch size, its amount reduces especially in 2016. An increase in the number of patches and reduction of mean patch increasing demonstrate that the tissue of residential are became fine and landscape of area is fragmented. The maximum of disturbance is corresponded to zones 5-11 where maximum changes, conversions and road network expansion occurs over the time and their lands (mainly barren) are replaced by man-made areas and road network. Human accessibility to land is positively related to its change and destruction rate and an addition of roads results in increasing the rate of change trend (Arumalani et al., 2004). Mean patch size and area-weighted mean patch fractal dimension increase in road network over the time, while the number of patches and area-weighted mean patch fractal dimension decrease in agricultural lands.
Regarding the industrial lands which were centralized in zones 6-10, they increased in 2008, while a decrease was observed in zones 8-10 in 2016. The number of patch represents a decreasing-increasing

trend from center to zone 6. Based on the metric of area-weighted mean patch fractal dimension, its value reduces over the time. Barren lands increase by moving from center toward edges. Over the time, a decreasing trend occurs in are as near the center, leading to great reduction over the time. The number of patches decreased in 1996, and increased during 2008 significantly, especially in zones 3-6, and finally minimized in 2016 with a significant decreasing trend. Mean patch size increases at the first, while it represents a decreasing trend in 2008 and 2016. Regarding the metric of area-weighted mean patch fractal dimension, a decreasing trend is observed from center toward edge, whilet here is an increasing trend in zone 8 and over. The shape of the borders related to the diverse natural covers of land is more complex compared to that in the covers derived from human activities. An increase in human disturbance results in decreasing the mean fractal dimension of patches (Turner & Ruscher, 1988). During 1996-2008, the amount of sequestration decreased in most areas instead of zone 6 where an increasing trend was observed due to an addition of green space area in this zone. Further, carbon sequestration rates significantly reduced in zone 3 due to the decrease of agricultural lands and increase in man-made uses.